VISION THROUGH VARIOUS SCUBA FACEMASKS

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SUMMARY PAGE

THE PROBLEM

To determine whether there are differences in various measures of a diver's visual performance (such as acuity, depth perception, field of view, etc.) when wearing different, commercially available, SCUBA facemasks.

FINDINGS

There are statistically significant differences between the various facemasks for every visual process tested, except one. Some masks are superior for one purpose, however, and inferior for another purpose.

APPLICATION

The results are applicable for the selection of the proper facemask for use in any particular Naval diving mission in which the diver's task might emphasize one aspect of visual performance over another.

ADMINISTRATIVE INFORMATION

This investigation was conducted as part of Bureau of Medicine and Surgery Research Unit M4306.03-2050DXC5. The present report is Number 14 on this work unit. It was submitted for review on 28 November 1972, approved for publication on 15 December 1972 and designated as NavSubMedRschLab Report No. 734.

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ABSTRACT

The visual performance of divers was compared utilizing five commercial facemasks. Measurements were made of visual fields, visual acuity, stereoacuity, hand-eye coordination, accuracy of distance estimates, and accuracy of size estimates at both near and far distances. In addition, the optical properties of the masks were measured and the susceptibility of each mask to fogging was tested. There were significant differences between the masks for every visual process tested. Some masks were superior for one purpose, and inferior for another purpose. For example, the compensating mask improved size and distance estimates and hand-eye coordination but degraded acuity and stereoacuity. In every test, the results for the goggles fell between those for the compensating mask and those for the other three masks. The results were not explained on the basis of susceptibility to fogging.

VISION THROUGH VARIOUS SCUBA FACEMASKS

INTRODUCTION

The SCUBA diver has available to him an almost bewildering assortment of facemasks from which to choose. When asked for the reason for his preference, each diver appears to be concerned with a different characteristic of the mask: the ease of clearing the mask of water; the softness of the rubber; the tightness of fit; the distance of the faceplace from the eyes; the field of view, etc. One Navy diver remarked, "Ask 10,000 divers and you will get 10,000 reasons."

Interestingly, the possibility of differential visual performance is rarely mentioned. Comparisons of visual performance through different facemasks appear to be limited to visual acuity[1] and perimetry.[2,3] The reason, probably, is that it is difficult to imagine that such basic visual processes as acuity or distance estimation would be affected by what must seem to be rather trivial differences in the configuration of the mask.

A number of studies, however, have shown that stereoacuity is affected by field of view and the visibility of peripheral objects.[4-7] And size estimates are affected by the "frame effect" resulting from field of view,[8] which in turn influences perception of distance. There is, thus, some basis for hypothesizing that certain aspects of vision may be better with some masks than others. In fact, a facemask is available which incorporates a lens designed to compensate optically[9] for the size and distance distortions under water.[10] But since accommodation has been shown to affect stereoacuity,[7,11] it seemed likely that stereoacuity would be affected by this mask.

Finally, it has long been the practice to subject new visors for aircraft pilots to optical evaluation.[12] It would seem to be eminently reasonable to develop analogous standards for divers' facemasks. For this reason we have conducted a similar evaluation on various diving masks worn by Navy divers.

Five facemasks considered to be representative of the wide variety available were selected for comparison. Measurements were made of field of view, visual acuity, stereoacuity, hand-eye coordination, accuracy of distance estimates, and accuracy of size estimates at both near and far distances. In addition the optical properties of the masks were measured and the susceptibility to fogging tested.

METHOD

Subjects

A total of about 150 different individuals served as subjects. Most were sailors at the Naval Submarine Base who volunteered for the study, but a number of civilian dependents and staff members of the Laboratory participated also.

Masks

The five masks evaluated were (1) a standard, oval mask (S), (2) a kidney

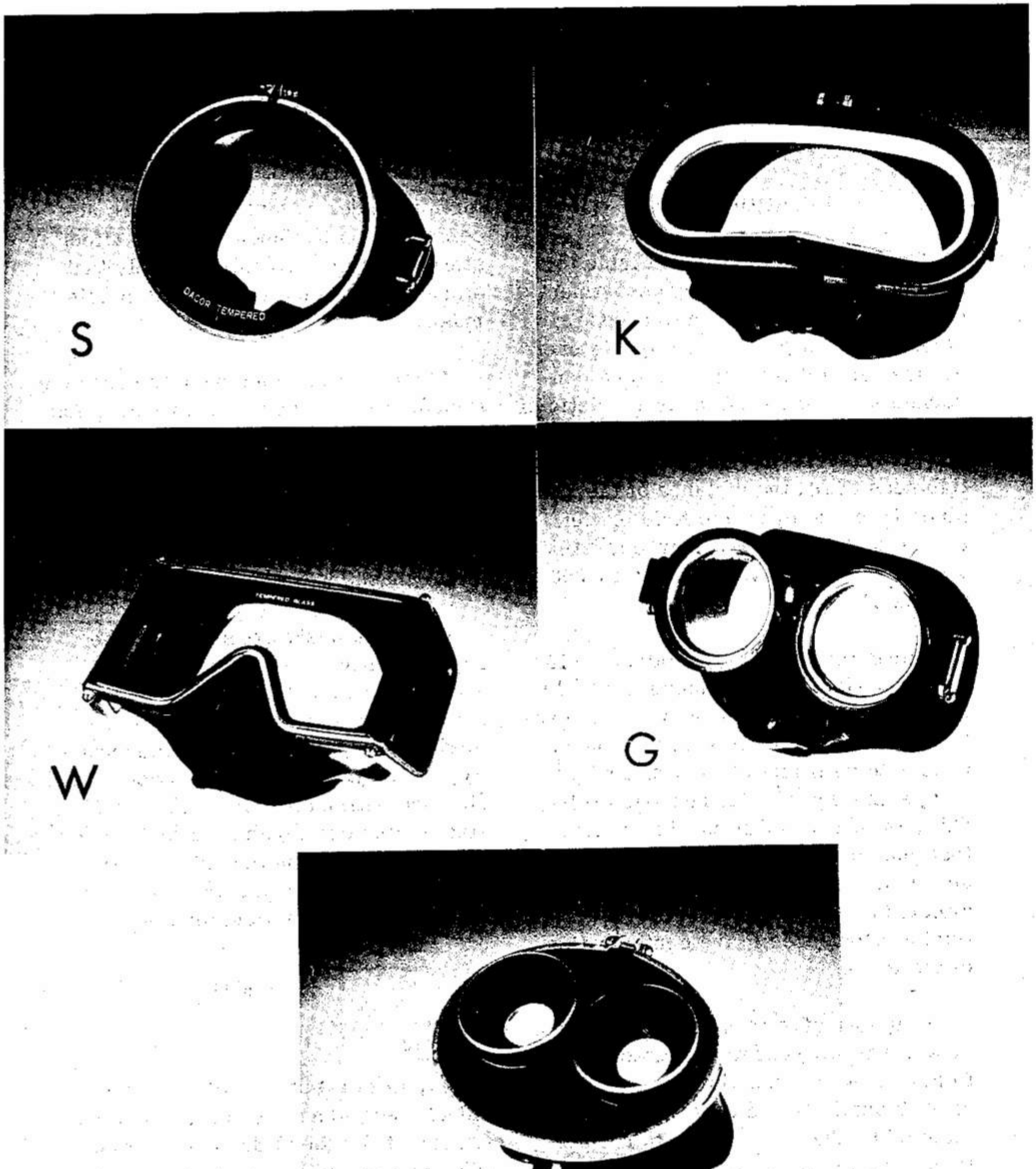

Fig. 1. The facemasks evaluated were standard, (S); kidney (K); widefield, (W); goggles, (G); and compensating, (C).

shaped mask (K), (3) a wrap-around, wide-field mask (W), (4) a goggle type mask (G), (5) a mask with a built-in lens system designed to compensate for visual distortions under water (C). These masks are shown in Fig. 1.

Apparatus and Procedure

1. Field of view was measured using an aluminum hemisphere 90 cm in diameter mounted on a tripod so that the hemisphere was at a 20° angle with the ground. The interior of the hemisphere was marked in 10 deg visual angle steps from the center to the outside edge along eight (horizontal, vertical and oblique) meridians. A rod across the center line served as a support for the facemask and two clamps on the rod served to center the mask. The diver bent over the hemisphere and kept his head motionless by pressing against the rod. He then placed his finger on the most peripheral point which he could see along each of the eight meridians. Viewing was binocular. Eight subjects were tested; each subject observed through all masks, which were presented in random order.

2. Visual acuity was measured using a set of high contrast black Landolt Cs on a white background encased in plastic. These targets were photographs of a Landolt C printed in different sizes. The width of the gap varied from 0.46 mm to 1.35 mm. The targets were presented through a circular, eye-level opening (5 cm diam.) in a white rectangle (46 x 53 cm). The distance of this apparatus was adjusted for each subject so that the smallest C could not be seen. The subject's head was positioned by a chin-rest and viewing was binocular. The acuity thresholds were measured with the method of constant stimuli. A set of 4 or 5 Cs was chosen which encompassed the subject's acuity threshold, and the targets were presented in random order. The C was presented with the gap in either the 3, 6, 9, or 12 o'clock position. These positions were presented in haphazard order, but care was taken to present the 3 and 9 o'clock positions half the time. A frequency of seeing curve was drawn on cumulative probability paper and the 50 percent size taken as threshold. Final acuity results were calculated taking into account both target size and viewing distance. Fifteen subjects were tested; each subject observed through all five masks in counterbalanced order.

3. Stereoscopic acuity was measured using a three-rod Howard-Dolman apparatus set 3 m from the subject. The vertical, black rods stood in a box with a gray front in the center of which was an aperture which subtended 2.4° x 6.6° visual angle. They were 1.58 cm thick and set at 7.6 cm intervals and were seen against a white background. The gray front subtended 7.6 x 9.5 deg visual angle. The stereoacuity thresholds were also measured using the method of constant stimuli. The middle (movable) rod was set at various positions and the subject judged whether it was closer or farther than the two outside rods. The variability of the equidistance settings was used for analysis. A frequency of seeing curve was drawn on cumulative probability paper and the standard deviations read directly from the graph. Fifteen subjects were tested. Each subject observed through all five masks in counterbalanced order.

4. Hand-eye coordination was measured using a standard technique.[13] Three dots were painted on the top of a white table 60 cm square ("hand-eye table"), and the subject's task was to make small Xs on the underside of the table as accurately as possible directly under these dots. With his chin in a chin-rest, the subject could see the dots but could not see his own hand. Three marks were made under each dot in random order during each test. The procedure was first carried out in air, and then in the water. Each subject was tested with only one mask; each mask was tested with 20 subjects.

5. Distance estimates were obtained as follows: The subject, positioned by a chin-rest, estimated the distance in feet of a fluorescent orange cylinder (7 cm diam., 12 cm high) suspended at eye level at test distances of 2, 5, 10, and 20 ft (0.6, 1.5, 3 and 6 m). Each of the four distances was presented twice, in random order. The view of the target was blocked between judgments. Each subject was tested with only one mask, the same one worn in the hand-eye coordination test. Each mask was tested with 20 subjects.

6. Size estimates were obtained for targets positioned both 30 cm and 3 m from the subject. At the near distance, the subject's task was to choose from a series of 16 numbered aluminum disks (whose diameters varied from 1.27 to 3.3 cm) those disks which matched in dize a dime, penny, nickel, and quarter. The disks were spread out on a table in a haphazard arrangement and the subject reported the number of the disk of his choice without touching it. At the far distance, his task was to choose from another series of 22 black disks (whose diameters varied from 3.2 to 25.4 cm) those disks which matched in diameter a golf ball, baseball, softball and basketball. The disks were suspended in a haphazard arrangement on a white vertical background; the subjects reported their choice without, of course, touching the disks. The estimates were first made in air and then in the water. Twenty subjects were tested; each observed through all five masks in counterbalanced order. Sets of disks with different numbers were used for each trial.

7. Optical properties. All the masks except the compensating mask (whose lenses were too thick for most of the testing instruments) were tested for spectral transmittance, refractive errors, prismatic deviations and distortions. The visible transmittance was measured with a Cary Spectrophotometer, Model 14, and calculated according to the CIE Computational Table for Illuminant C.[14] The horizontal and vertical prismatic deviations were determined with a 10 power transit and an appropriate target 35 feet away. The spherical and cylindrical powers were measured with a Bausch & Lomb Vertometer which measured from -0.25 to +0.25 D in 0.01 steps. Distortion was measured with an Ann Arbor Optical Co. Model "B" Optical Tester with a 60-line grating and ancillary equipment. All five masks were tested with the A.O. Colmascope and B&L Polariscope for heat tempering and strains. Finally, C.I.E. x,y coordinates were calculated to determine whether or not the faceplates were chromatically neutral.

8. Susceptibility to fogging was determined by measuring how long a diver could continue to see a very low contrast target through the various masks when no effort was made to clear the mask or prevent its fogging. A gray annulus 2 cm outside diameter and 0.5 cm thick on a 5 cm square gray background was the target. The contrast of the annulus according to the formula $L_T - L_B / L_B$ was 20 percent. For each mask, the target was set by the method of limits at the farthest distance at which it was just visible through a newly cleared mask. The diver then rinsed his mask for the last time and submerged. He was then repeatedly shown either the front or the back of the 5 cm square in random order as rapidly as possible. His task was to signal whether or not the annulus was present. The procedure was continued until he had made two consecutive errors. Twenty subjects were tested with every mask; the masks were presented in counterbalanced order.

RESULTS

Field of View

Figure 2 shows the extents of the fields of view afforded by the masks. Table 1 presents the mean vertical and horizontal diameters of the fields. The results show the reduced field of view available through the goggles and the compensating mask and the slightly larger field of view through the wide-angle mask compared to that seen through the standard mask. The field of view through the standard mask is roughly circular with a diameter of about 85 deg visual angle, almost exactly that measured by Weltman, Christianson, and Egstrom[3] in a different apparatus. The present results also show the loss of the lower portions of the visual field through the kidney mask pointed out by Weltman *et al.*

Visual Acuity

The mean and median gap widths in min visual angle resolved by the 15 subjects through the five masks are given in Table 2. There was no difference between the results for the standard, kidney, and widefield masks; mean acuity was slightly worse through the goggles and considerably worse through the compensating mask.

An analysis of variance showed the masks to be significantly different ($F=13.22$, $df=4$, $p<.001$). The Tukey (a) analysis[15] indicated that the compensating mask was significantly different from each of the other four masks ($p<.01$), but the other four masks did not differ significantly.

Stereoacuity

Table 3 gives the mean and median stereoacuity thresholds in terms of variability of the equidistance settings for the 15 subjects. It is interesting to see that the best threshold was obtained with the widefield mask and the worst threshold with the goggles, in conformity with our previous results,[4] although an analysis of variance indicated that these results fell just short of statistical significance.

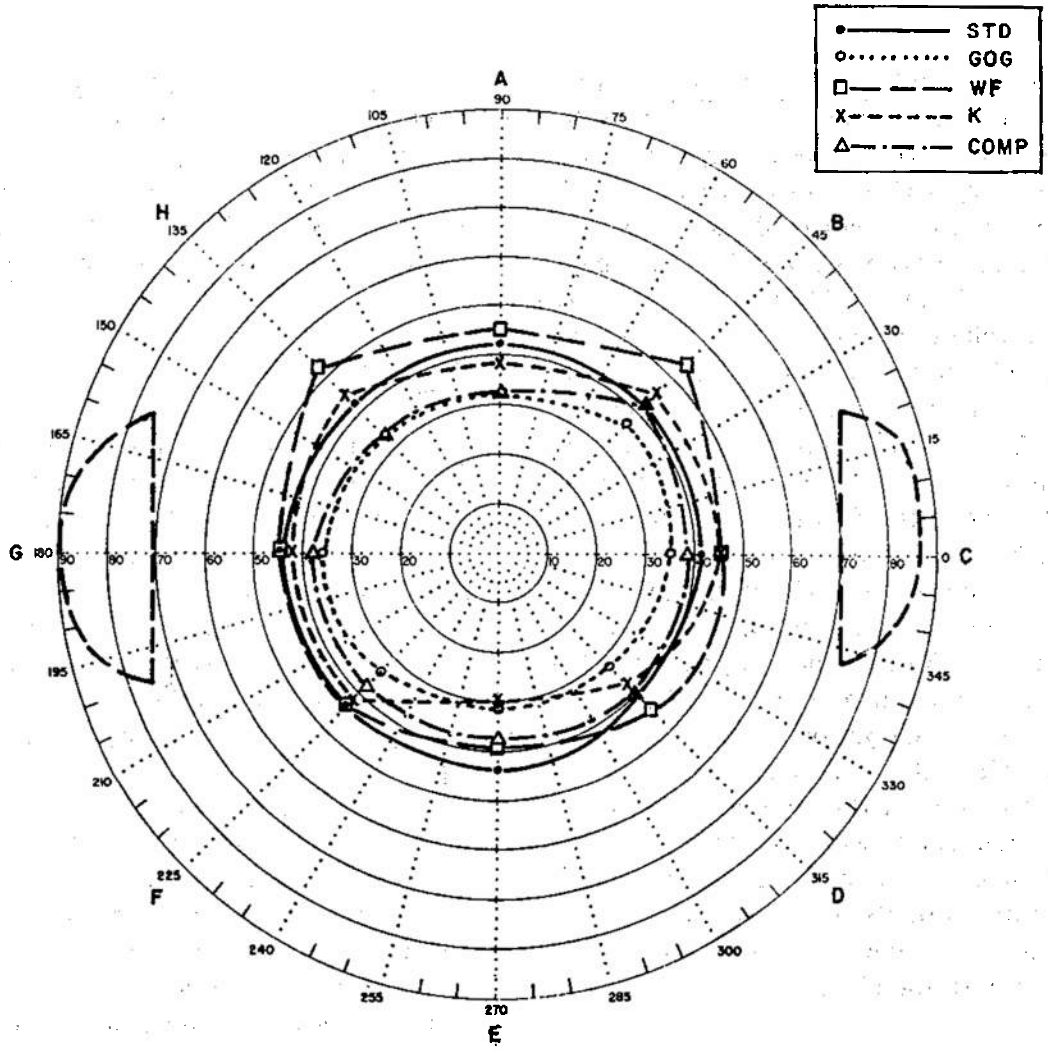

Fig. 2. Field of view afforded by the various facemasks. (standard, •; kidney, x; widefield, □; goggles, o; compensating, Δ).

Hand-Eye Coordination

In the water, the apparent position of the dots is typically shifted both toward the subject and (unless the line of sight to the dot is perpendicular to the faceplate) laterally toward the sides of the table. Since we have found the lateral measurements to be highly variable and inconsistent, the present analysis was restricted to the distortions toward and away from the subject.

Table 4 gives the mean magnitude of shift of the Xs in the water from their position in air. A positive number indicates that the shift was in the expected direction toward the subject. A negative number indicates that the shift was away from the subject. Table 4 shows that with the standard mask, the mean shift in the position of the Xs was 3.86 cm toward the subject, as would be expected. With the widefield mask, virtually the same result occurred. There

Table 1. Mean Field of View (deg vis angle)

Mask	Vertical Diameter	Horizontal Diameter
Standard	86	86
Kidney	70	90
Widefield	84	87*
Goggles	63	72
Compensating	70	75

* plus 18° more on sides

Table 2. Resolution Acuity as Indicated by Gap Width of Landolt C in Min Arc Visual Angle

Mask	Mean	Median
Standard	.80	.78
Kidney	.84	.86
Widefield	.86	.84
Goggles	.97	.96
Compensating	1.20	1.11

Table 3. Stereoacuity (η_σ in sec arc)

Mask	Mean	Median
Standard	10.3	7.0
Kidney	8.5	7.8
Widefield	8.8	5.6
Goggles	13.5	9.9
Compensating	13.5	9.9

Table 4. Mean Magnitudes of Distortion (cm) Toward and Away From the Subject

Mask	Mean	σ
Standard	3.86	$\pm$ 1.70
Kidney	2.36	$\pm$ 2.03
Widefield	3.61	$\pm$ 2.20
Goggles	1.02	$\pm$ 3.43
Compensating	-1.25	$\pm$ 1.93

was slightly less shift through the kidney mask and considerably less shift through the goggles. With the compensating mask, there was no mean shift in the expected direction at all; rather there was a shift of 1.25 cm away from the subject.

An analysis of variance showed these differences to be highly significant ($F=16.1$, $df=4, 95$, $p<.001$). The Tukey (a) analysis showed that the compensating mask resulted in significantly less distortion than did the standard, widefield and kidney masks ($p<.01$) or the goggles ($p<.05$). The goggles too resulted in less distortion than did the standard or widefield masks ($p<.01$).

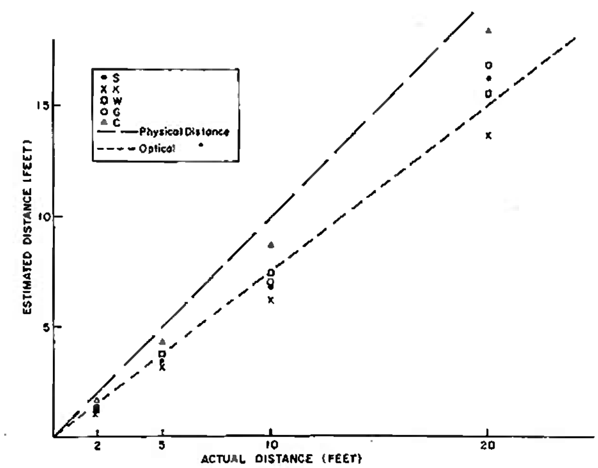

Fig. 3. Geometric means of distance estimates through the five masks for targets at four distances from diver.

Distance Estimates

The geometric means of the distance estimates are shown in Fig. 3 for the five masks (20 different subjects for each mask). The actual distance of the target was always underestimated. The degree of underestimation was greatest with the kidney mask and least with the compensating mask. As has been true with the other measures, the results for the goggles are between those for the compensating and the other masks except at a target distance of 10 ft. The masks are significantly different ($F=4.59$, $df=4, 95$, $p<.01$). The Tukey (a) analysis shows that the distance estimates made through the compensating mask are significantly more accurate than those made through any of the other masks ($p<.01$) whereas those made through the kidney mask were also significantly less accurate ($p<.01$) than those made through the goggles and widefield mask.

If optical refraction were the only effective variable, the distance estimates would be expected to be about .75 of the physical distance, but the estimates tended to be smaller than .75 at the nearer distances and larger than .75 at the farthest distance. This conforms with our previous findings that distances are increasingly overestimated, relative to the .75 value, as distance is increased due to turbidity of the water.[16-18] The estimates are less than .75 of the actual distance at the nearer distances because of a general tendency to underestimate even in air. Thus, even though some underestimation still occurred for the compensating mask, the estimates were actually quite similar to the values which are usually obtained in air.

Size Estimates

The mean size-estimates of the disks chosen as equal to the four coins are shown in Fig. 4. The results are also

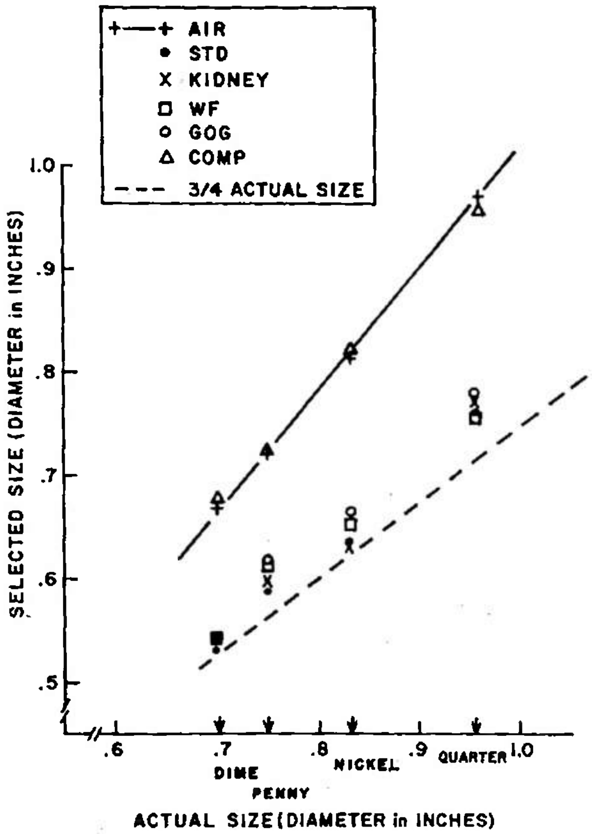

Fig. 4. Mean sizes of disks selected as equal to four coins set at 30 cm from diver through the five facemasks.

presented in Table 5 as ratios of the diameters of the disks selected in the water to the diameters of the disks selected in the air. The table also shows the ratios of the diameters selected in air to the actual diameters of the four coins.

First of all, the "air ratios" in Table 5 show that the subjects were able to estimate the sizes of the coins quite accurately in air. The smaller coins were underestimated and the largest coin was slightly overestimated, but the mean size estimate was .98 of the correct value. Interestingly, the amount of underestimation increased with decreasing size of coin.

Except through the compensating mask, the size estimates are virtually identical. They are uniformly about .80 of the true size. The mean size estimate through the compensating mask, however, was virtually identical to the values in air. It is interesting that once again the mean value for the goggles is closer to that for the compensating mask than is the mean for any of the other masks. The masks are significantly different according to an analysis of variance ($F=47.25$; $df=4, 19$, $p<.001$). According to the Tukey (a) analysis, the compensating mask is significantly different ($p<.01$) from each of the other masks.

The results at the far distance of 3 m are given in Fig. 5 and Table 6. The estimates in air were less accurate than for the coins, but this may simply be a function of familiarity. The balls were all overestimated, again increasingly so with increasing size.

Once again, the compensating mask permitted the most accurate estimates and the goggles were intermediate between the compensating and the remaining three masks. The mean size estimates tended to be somewhat larger at the far distance than at the near distance, but this was the result of the large values for the golf ball. The masks are significantly different according to an analysis of variance ($F=10.33$, $df=4, 19$, $p<.05$). The Tukey (a) analysis shows the estimates

Table 5. Accuracy of Size Estimates at the Near Distance of 30 cm. Ratio of Diameter of Disk Selected in the Water to That Selected in Air

Mask	Dime	Penny	Nickel	Quarter	Mean
Standard	.80	.81	.78	.78	.80
Kidney	.81	.82	.78	.80	.80
Widefield	.81	.85	.80	.78	.81
Goggles	.81	.85	.82	.80	.82
Compensating	1.02	1.01	1.01	.98	1.00
Air Ratio	.95	.96	.97	1.02	.98

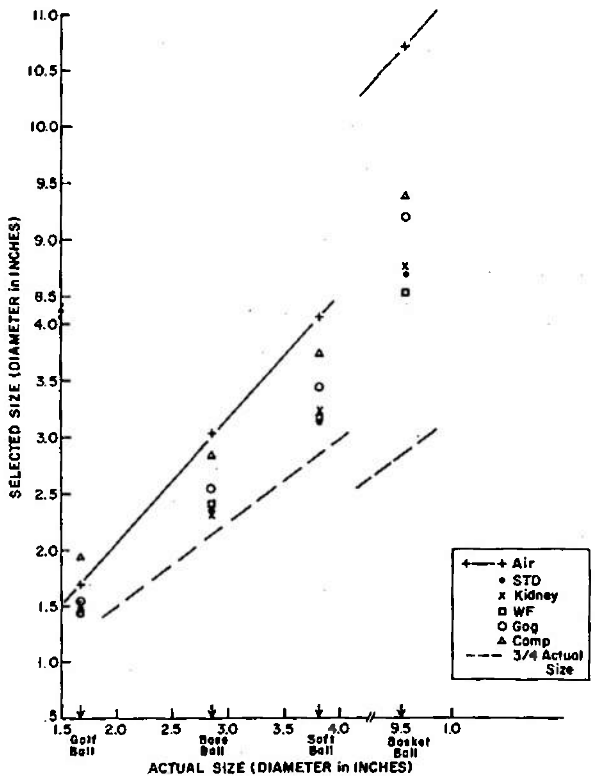

Fig. 5. Mean sizes of disks selected as equal in diameter to that of four playing balls at a distance of 3 m through the five facemasks.

through the compensating mask to be significantly better than those through the standard and widefield masks ($p < .01$) and better than those through the kidney and goggles ($p < .05$); in addition, the estimates through the goggles are significantly better ($p < .05$) than those through the widefield mask.

A comparison of Figs. 4 and 5 shows that the mean estimates at the near distance were much closer to the values expected on the basis of retinal image size as a result of refraction. A likely reason is that at the near distance there is additional distorted distance information from accommodation and convergence, and this reinforces the erroneous information provided by retinal image size; all these cues converge to produce a size-estimate conforming to optical predictions. At the far distance, however, the distorted distance cues from accommodation and convergence are ineffective[19] leading to more accurate results.

Table 6. Accuracy of Size Estimates at the Far Distance of 3 m. Ratio of Diameter of Disk Selected in the Water to That Selected in Air

Mask	Golf ball	Baseball	Softball	Basketball	Mean
Standard	.91	.77	.77	.81	.82
Kidney	.86	.77	.80	.82	.81
Widefield	.84	.80	.78	.79	.80
Goggles	.91	.83	.85	.85	.86
Compensating	1.14	.94	.92	.88	.97
Air Ratio	1.01	1.06	1.07	1.12	1.07

Optical Properties

The results of the optical evaluation are presented in Table 7. The visible transmittance was the same for the standard and kidney masks, and only slightly less for the goggles and widefield mask. The compensating mask, because of its lens system, of course, had a substantially reduced transmittance. All faceplates were neutral in color, as compared to the C.I.E. x, y coordinates for Illuminant C (x= .3101, y= .3163, z= .3736). The prismatic deviations and the spherical and cylindrical errors were all negligible. All masks were tempered.

There are, as yet, no standards for diving masks, but it is interesting to evaluate these results against the NavSubMedRschLab standards for glass and plastic plano visors.[12] The masks would all meet these standards except for their visible transmittance; this should be at least 90 percent. The compensating mask fails this by a wide margin, and the goggles and widefield mask are marginal failures.

Susceptibility to Fogging

The results of the fogging test are shown in Table 8. The standard and widefield masks permitted the longest runs; unexpectedly, the kidney mask fogged most quickly. These differences are highly significant according to an analysis of variance ($F= 8.25$, $df= 4,76$, $p<.001$). The Tukey (a) analysis shows the widefield mask to be significantly better ($p<.01$) than the goggles, kidney, and compensating masks; in addition, the standard mask is better ($p<.05$) than the kidney mask.

Table 7. Optical Properties

	Standard	Kidney	Widefield	Goggles	Compensating
Visible transmittance	.90	.90	.89	.89	.70
CIE Coord. x	.3088	.3090	.3080	.3106	.3118
y	.3166	.3168	.3169	.3189	.3212
z	.3745	.3740	.3749	.3704	.3670
Prismatic deviation	.06 D	.06 D	0	.06 D	*
Spherical or cylindrical power	.06 D	.01 D	.06 D	.06 D	*
Distortion	Satisfactory; Moderate distortion	Satisfactory	Satisfactory	Satisfactory; Moderate distortion	

* Could not be tested with our equipment.

Table 8. Time (seconds) Elapsed Before Two Errors in Detection of Low Contrast Target Were Made

Mask	Mean	Median
Standard	57.6 ± 33.3	48.0
Kidney	31.1 ± 19.2	23.5
Widefield	74.0 ± 61.3	47.5
Goggles	42.2 ± 28.2	35.5
Compensating	35.2 ± 22.4	31.0

In an attempt to check these results, a slightly different procedure was also carried out. The smallest, high-contrast Landolt-C used in the visual acuity experiment which a diver could resolve at a given distance through a given mask was repeatedly shown in various orientations until he could no longer respond correctly. This was repeated five times for each mask with two divers. The results were the same as with the large, low contrast annulus. The mean time in seconds to criterion were: widefield, 51; standard, 50; goggles, 40; compensating, 34; and kidney, 31.

It is hard to explain the high susceptibility to fogging shown by the kidney mask. We hypothesized that the rate of fogging might be correlated with two variables, (1) the volume of air space between the mask and the face, and (2) the distance of the faceplate from the eyes. The volume of the masks was determined by filling the mask with water while it was being worn by a diver whose fogging results conformed with the group mean. Both sets of findings are given in Table 9. Neither serves to explain the poor results for the kidney mask.

DISCUSSION

There are significant differences in the performance of divers on the various measures of visual performance through different facemasks. The most obvious visual distortions in the water are that objects appear to be enlarged by about 30 percent and located at only 3/4 their actual distance from the observer. The present results show that the compensating mask has been well designed to eliminate such perceptual errors. Perception of size both at near and far distances (Tables 5 and 6) are generally quite accurate, certainly far more accurate than through any of the other masks. Similarly, distance estimates (Fig. 3) are significantly more accurate for targets at distances ranging from 2 to 20 ft. Hand-eye coordination (Table 4) was also more accurate than any other mask except for the goggles; it was, indeed, significantly different from every other mask in that it did not exhibit the usual direction of distortion at all; rather, the compensating mask over-compensated for the perceptual distortion in this situation and introduced an error in the direction opposite to that expected which was slightly greater than the error found with the goggles.

Table 9. Volume of Air Space Between Mask and Face and Distance Between Inner Surface of Faceplate and Cornea

Mask	Volume (cc)	Distance (cm)
Standard	250	3.30
Kidney	300	2.81
Widefield	350	2.60
Goggles	170	2.73
Compensating	270	1.75

But the compensating mask pays for these gains to some extent with losses in both resolution and stereoacuity. The decline in resolution acuity is to be expected, since the mask reduces the size of the retinal image, whereas the typical SCUBA mask permits refraction to operate and thereby increases the size of the image. Thus, in clear water with a standard mask, visual acuity may be better than it is in air.[1,20] In addition, Table 7 shows that the compensating mask reduces the light transmittance much more than do the other masks, which would also be expected to contribute to a decline in visual acuity.

The decline in stereoacuity with the compensating mask is of considerable interest. Recent work has shown that stereoacuity declines as the field of view constricts.[4,6] Thus, the present results conform to those of previous studies in that stereoacuity tends to be best for the widefield mask and worst for the goggles and the compensating mask which have the narrowest field of view. Now, other experiments have indicated that the observer's state of accommodation is also a potent factor in stereoacuity; as accommodation is relaxed, stereoacuity has been found to improve.[11] Since the compensating mask increases the apparent distance of objects and therefore presumably reduces the level of the diver's accommodation, it might be expected that stereoacuity would improve. That it did not is most likely due to the fact that the target distance was 3 m, beyond the range in which changes in accommodation appear to play much of a role in visual perception.[19] The present results confirm, however, that the size of the visual field is an important factor.

One other point appears to be related to this and is worth mentioning. It is that the results for the goggles on all the tests of visual performance were intermediate between those for the compensating mask and those for the other three masks. The only similarity between the compensating mask and the goggles is in the field of view, which is virtually identical for these two masks and is considerably smaller than that for the other three. This suggests the possibility, noted above, that extent of field of view is a more potent variable than was previously suspected.

In summary, the widefield mask produces the most extensive field of view, although not as extensive as would be expected from looking through the mask in the air. The compensating mask does an excellent job of compensating for the distortions of size and generally permits better estimates of distance and hand-eye coordination than the other masks. However, it significantly reduces both resolution and stereoacuity. The standard, kidney, and widefield masks are quite similar. They permit the same visual acuity, hand-eye coordination, distance and size estimates. The widefield tends to give somewhat better stereoacuity. The goggles were more like the compensating mask in every task; that is, visual acuity and stereoacuity were somewhat reduced, hand-eye coordination, and distance and size estimates were somewhat improved.

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13. ABSTRACT

The visual performance of divers was compared through five commercial facemasks. Measurements were made of visual fields, visual acuity, stereoacuity, hand-eye coordination, accuracy of distance estimates, and accuracy of size estimates at both near and far distances. In addition, the optical properties of the masks were measured and the susceptibility of each mask to fogging was tested. There were significant differences between the masks for every visual process tested. Some masks were superior for one purpose and inferior for another purpose. For example, the compensating mask improved size and distance estimates and hand-eye coordination but degraded acuity and stereoacuity. In every test the results for the goggles fell between those for the compensating mask and those for the other three masks. The results were not explained on the basis of susceptibility to fogging.

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